DOCUMENT RESUME

ED 092 599 TM 003 712

AUTHOR Potts, George R.
TITLE How Subjects Do not Store and Retrieve Information About Ordered Relationships.
PUB DATE [73]
NOTE 18p.; Paper presented at the Annual Meeting of the Psychonomic Society (14th, St. Louis, Missouri, November 1973)

EDRS PRICE MF-$0.75 HC-$1.50 PLUS POSTAGE
DESCRIPTORS *Cognitive Processes; College Students; Deductive Methods; Logic; *Reaction Time; *Retention
IDENTIFIERS *Linear Ordering

ABSTRACT

Subjects learned and answered questions about four- or six-term linear orderings (e.g., Tom is taller than Dick, who is taller than Sam, who is taller than Pete). Such an ordering is comprised of some adjacent pairwise relations that are necessary to the establishment of the ordering (e.g., Tom is taller than Dick, Dick is taller than Sam), and some remote relations that are deducible (e.g., Tom is taller than Sam). Except for unusually fast responses to test sentences beginning with an end term, reaction time was a monotonic decreasing function of remoteness; the more remote the shorter the reaction time. This result contradicts several current models of how meaningful information is stored. First, it contradicts any model which argues that subjects do not store deducible information. Information pertaining to the deducible remote pairs is stored along with the information that was actually presented. Second, it contradicts any model which describes the form of the stored information in terms of inter-item associations. A model which can account for the result is presented. (Author)

How Subjects Do Not Store and Retrieve Information About Ordered Relationships[1]

George R. Potts

Dartmouth College, Hanover, N. H. 03755

Most current accounts of how meaningful material is encoded and stored assume that the individual sentences in the text are combined both with each other and with Ss' generalized knowledge of the world to form an abstract representation of the general idea underlying the passage. This assumption is necessary in order to account for the now well-established finding that Ss have considerable difficulty distinguishing between information which was actually presented and information which had to be inferred from the presented material (Bransford & Franks, 1972; Bransford, Barclay, & Franks, 1972; Barclay 1973; Potts, 1973).

In an attempt to discover the nature of the abstract ideas generated and stored by Ss in the process of reading text, Potts (1972) presented Ss with a paragraph describing a linear ordering of four terms (e.g., Tom is taller than Dick; Dick is taller than Sam; Sam is taller than Pete). Such an ordering (which will be characterized as $A > B > C > D$) is comprised of six pairwise relations. The three adjacent pairs ($A > B$, $B > C$, $C > D$) are necessary to the establishment of the ordering. The three remote pairs ($A > C$, $B > D$, $A > D$) are deducible from some subset of the adjacent pairs.[2] After studying the ordering, Ss were tested for their knowledge of all six pairs. Proportion correct was higher and reaction time shorter on the remote pairs than on the adjacent pairs. This was the case even when the remote pairs were never presented and thus had to be deduced from the adjacent pairs. This result contradicts several possible explanations of how such information might be stored.

Some researchers have argued that when faced with a piece of deducible information, Ss do not store it (e.g., Quillian, 1969). Instead, it is argued that Ss rely on the seemingly efficient strategy of storing only the necessary information (in this case, the adjacent pairs) and deducing the remaining information whenever required to do so. A special case of this position would be that Ss encode the information by forming associations between the adjacent elements of the ordering and deduce the remote relationships by associationistic chaining. Potts' (1972) result clearly contradicts this general point of view. If Ss stored only the adjacent pairs and deduced the remote pairs when tested, then proportion correct on a remote pair could not possibly be higher than proportion correct on any of the adjacent pairs necessary to deduce it. Similarly, in order to respond to a remote pair, Ss would have to retrieve all the relevant adjacent pairs and then draw the inference. Hence, reaction time to a remote pair would have to be longer than reaction time to any adjacent pair necessary to deduce it. It is obvious that Ss in Potts' experiment must have stored information about the deducible remote pairs along with information about the adjacent pairs.

Several researchers have come to accept the position that Ss do indeed store deducible information (e.g., Rumelhart, Lindsay, & Norman, 1972; Anderson & Bower, 1973). Though these models are similar in terms of the form in which deducible information is stored, the model of human associative memory proposed by Anderson and Bower (1973) is more explicit than most and will be singled out for closer examination. This model describes the encoding of ordered relationships in terms of an associationistic chain with remote associations, much like the description proposed by Ebbinghaus (1885; as reported in Young, 1968). Such a model has the same strengths and weaknesses as any model which argues that Ss deduce the remote pairs while studying the text and store these pairs along with the adjacent pairs that were actually presented. Since Ss can be correct on a remote pair by either remembering that pair or by remembering some set of other pairs necessary to deduce it, such a model can account for the fact that proportion correct on the remote pairs is better than proportion correct on the adjacent pairs.

Though the model can account for the high proportion correct on the remote pairs, it cannot account for the fast reaction time to those pairs. It must be assumed that some Ss will have responded correctly to a remote pair because they remembered that pair while others will have responded correctly because they correctly deduced it. When Ss remember the remote pair, reaction time to the pair should be comparable to reaction time to an adjacent pair since both need only to be retrieved from memory in order to answer the question (actually, since Anderson and Bower concur with Ebbinghaus in assuming that the more remote an association, the weaker it is, reaction time even in this case should still be somewhat longer on the remote pair). When Ss are forced to deduce the remote pair, on the other hand, reaction time should be very slow. Hence, the model must predict that overall reaction time to the remote pairs should be longer than overall reaction time to the adjacent pairs. This model is therefore contradicted by Potts' (1972) result.

The present series of experiments was designed to verify Potts' (1972) results and to develop a model of how Ss do indeed store and retrieve information about ordered relationships.

Experiment 1

Potts' original experiment was performed using only two different linear orderings, and proportion correct was sufficiently low that one might question the interpretation of the reaction time scores. Experiment 1 was designed to provide a replication of Potts' experiment which was not susceptible to these criticisms.

Method

Subjects. Subjects were 10 Dartmouth undergraduates who participated to fulfill a course requirement. Each participated in two 40-min sessions with one day intervening between the two sessions.

Materials. Materials consisted of a set of 20 paragraphs, each describing a four-term linear ordering (A > B > C > D). All terms were common one-syllable nouns of three to six letters, and no two terms of any one relation began with the same letter. The comparative adjectives used in each paragraph were chosen from the linguistically unmarked set: better, more, deeper, thicker, taller, higher, faster, and longer. Each ordering was described by presenting the three adjacent pairs comprising that ordering (A > B, B > C, C > D). The order of presentation of these pairs was varied. In four paragraphs the pairs were ordered C > D, A > B, B > C; in four paragraphs they were ordered B > C, A > B, C > D. In the remaining paragraphs the pairs were ordered A > B, B > C, C > D. A sample paragraph is given in Table 1.

Insert Table 1 about here

A set of 12 test sentences (six true and six false) was used to test *S*s' knowledge of the information in each paragraph. The six true test sentences consisted of a statement of the six pairs (three adjacent and three remote) comprising the ordering. The remote pairs (A > C, B > D, and A > D), it will be remembered, were never actually presented and thus had to be deduced from the adjacent pairs. For each true test sentence (e.g., A > B?), there was a corresponding false sentence comprised of the same two terms in reverse order (e.g., B > A?). All test sentences employed the linguistically unmarked form of the comparative adjectives. The test sentences were listed on a computer printout for presentation. The order of presentation of the sentences was randomized for each paragraph and for each *S*.

Procedure. After having heard the initial instructions, *S*s were given a sheet of paper on which the first paragraph was typed. They were allowed as much time as they desired to study the paragraph and were given a paper and pencil which they could use to take notes. When *S* indicated he was ready, the paragraph and notes were taken away, and he began responding to the first set of questions.

The stimulus sentences were presented to each S one at a time by use of the paper-advance mechanism from a high-speed printer. Subjects responded by pushing one of two microswitch buttons on a response box in front of them: the button marked "true" if they felt the sentence was true, the button marked "false" if they felt the sentence was false. A Lafayette Model 54517 millisecond reaction-time clock was started simultaneously with the presentation of a test sentence and was stopped automatically when one of the response buttons was pressed. After responding to a test sentence, Ss' response and reaction time were recorded manually by E. The next test sentence was then presented. This procedure was repeated until all 12 test sentences pertaining to the first paragraph had been presented. After responding to these 12 test sentences, the second paragraph was presented for Ss to study.

Subjects learned 10 of the paragraphs during the first session and the remaining 10 during the second. The first paragraph in each session was treated as a warm-up and was not scored. Subjects were instructed to respond to each test sentence as fast as possible but not to sacrifice accuracy. The importance of not making errors was stressed. To reduce the error variance of the reaction times, Ss were instructed to position their hands so that their left thumb rested on the left response button and their right thumb rested on the right response button. For each S, the labeling of the buttons was reversed in the two sessions. For approximately half the Ss, the buttons were labeled true-false during the first session and false-true during the second. For the remaining Ss, the buttons were labeled false-true during the first and true-false during the second session. Subjects were alerted to the shift in button position prior to participating in the second session.

Results

Overall proportion correct was .95. In fact, only two of the 10 Ss had an overall proportion correct under .95. These two Ss scored .83 and .90, respectively. If the scores of these two low performers are deleted, overall proportion correct is raised to .97. Hence, the level of performance was very high.

The reaction time profile for the 12 test questions averaged over Ss and paragraphs is presented in Figure 1. This profile,

----

Insert Figure 1 about here

----

it can be seen, is very similar to those reported by Potts (1972). Of special note is the obvious interaction between the specific pair and the truth value of the test sentence. When tested using a type of pair x truth value repeated measures analysis of variance, this interaction proved to be highly significant, $F(5,45) = 23.78$, $p < .001$.

Overall reaction times to the adjacent and remote pairs were 1.79 and 1.45 sec, respectively. Averaging over paragraphs, this superiority on the remote pairs was demonstrated by all 10 *S*s; averaging over *S*s, this effect was observed for all 18 scored paragraphs. Hence, the results of Potts (1972) were confirmed in that reaction time to the remote pairs, which had to be deduced, was consistently shorter than reaction time to the adjacent pairs, which were actually presented. This difference was, of course, highly significant by a sign test, $z = 2.85$, $p < .01$.

Discussion

The present results confirm the results and conclusions of Potts (1972). Since reaction time was faster on the remote pairs than on the adjacent pairs, it is clear that *S*s did not merely store the adjacent pairs and deduce the remote pairs when tested. Similarly, the construction of the four-term ordering could not have been accomplished by merely establishing simple associative links between the adjacent elements. Allowing for the possibility of remote associations also fails to save this associative theory for the reasons described earlier. Hence, the data contradict Anderson and Bower's model of human associative memory. More generally, the data contradict any model which describes the nature of the stored information in terms of inter-item associations.

How, then, does one account for the short reaction time to the remote pairs? One question that arises immediately is whether reaction time is a simple inverse function of the distance separating the terms of the pair being tested (i.e., the larger the distance, the shorter the reaction time). Such a distance model makes a total of nine ordinal predictions for true sentences and nine for false. According to such a model, reaction time to the pair A > D should be shorter than reaction time to any of the other five pairs; reaction time to the pair A > C should be shorter than reaction time to either A > B or B > C; and reaction time to the pair B > D should be shorter than reaction time to either B > C or C > D. All 18 ordinal predictions are satisfied by the present data.

If distance were the only factor operating, however, one would predict that the relative ease of responding to each of the six pairs should be the same for true and false sentences. Thus, the strong interaction between particular pair tested and truth value of the test sentence contradicts a simple distance model. In fact, this interaction is problematical for any model which attempts to explain the reaction time profile solely in terms of the form in which the information is stored. To account for this interaction, one must postulate a specific strategy for retrieving the stored information. Such a model will now be proposed.

A model for answering questions about ordered relationships

The present data can be accounted for by a model which assumes that Ss can store two kinds of information about an item. One kind consists of some measure of the magnitude or position of the item with respect to the other items in the ordering. If the item is an end term, Ss may also have stored the information that the item is first or last in the ordering.

Typically, in responding to a test sentence, S will examine the first term in the test sentence and retrieve the information he has stored about it. He will then do the same for the second term in the test sentence, perform some comparison operation and, on the basis of the results of that operation, respond true or false. The time required to complete the comparison operation is presumed to be inversely related to the distance separating the two terms; the larger the distance, the shorter the reaction time. If the first term in the test sentence is an end term and S has stored the fact that it is first or last, however, he can bypass both the retrieval of the information about the second term and the comparison stage. If this first term in the test sentence is A, he can respond immediately that the sentence is true; if the first term is D, he can respond immediately that it is false.

The present model is similar to the one originally proposed by Potts (1972), except that according to the original model an end term could affect responding regardless of whether it was the first or second term in the test sentence. According to the present model, the end term must appear as the first term in the test sentence in order to facilitate reaction time. If the end term is the second term in the test sentence, then Ss must retrieve information about both terms just as when there are no end terms, and the benefit of having an end term is lost. The present model easily accounts for the interaction between specific pair tested and truth value of the test sentence. Reaction times to true sentences containing the term A are shorter than reaction times to false sentences containing A because only in a true sentence does the A appear as the first term (e.g., A > B?). Similarly, reaction times to false sentences containing the term D are shorter than reaction times to true sentences containing the term D because only in a false sentence does the D appear as the first term (e.g., D > C?).

If S has successfully stored the fact that the term A is first, then reaction times to all test sentences having an A as their first term should not only be short, but also identical. This follows from the fact that if S realizes that the first term in the test sentence is the first term in the ordering, he will respond "true" immediately, without bothering to process the second term. The present data support this prediction in that reaction times to the three test sentences beginning with A are uniformly short.

If S has successfully stored the information that D is the last term in the ordering, then reaction times to all three test sentences beginning with D should also be uniformly short. This was not the case. Though the three sentences beginning with D are indeed next shortest, they are not all equal. A distance effect can be observed among these pairs in that reaction time to the pair D > A? was noticeably shorter than reaction time to D > B? or D > C?.

This discrepancy can be accounted for by hypothesizing that though virtually all Ss store the information that A is the first term in the ordering, only some Ss code the fact that D is last. Those that do store this information will have uniformly short reaction times to sentences beginning with D; those that do not will demonstrate the usual distance effect.

One way to test this hypothesis is by examing the reaction time profiles of individual Ss. Unfortunately, Experiment 1 does not provide enough data on a single S to yield a definitive answer. Experiment 2 was designed to do this.

Experiment 2

Method

Four Ss were employed in the present experiment. Each was paid $12 for participating in six 40-min sessions. Subject MB was a female freshman at Dartmouth College. Subject RL was 21 years old, the wife of a student, and had completed three years towards her bachelor's degree. Subject PG was a male sophomore at Dartmouth College. Subject XZ was 21 years old, the wife of a student, and had completed two years towards her bachelor's degree.

The apparatus, materials, and procedure were identical to those employed in Experiment 1 except for the modifications described herein. After each response, that response and its reaction time were manually recorded on the Dartmouth Time-Sharing System via a teletype in the experimental room. Following each set of 12 sentences, the number of errors S had made was printed out on the teletype, and E passed this information on to S.

The present experiment used the same 20 paragraphs employed in Experiment 1. Subjects were given paragraphs 1-10 on the first, third, and fifth sessions and paragraphs 11-20 on the second, fourth, and sixth sessions. The order of presentation of the test sentences was randomized for each session and for each S. For two Ss, the buttons were labeled true-false during the first session; for the other two Ss, the buttons were labeled false-true. The arrangement of the buttons was reversed for each session. As before, the first paragraph in each session was treated as a warm-up and was not scored.

Results and Discussion

Overall proportions correct for Ss MB, RL, PG, and XZ were .98, .91, 1.00, and .97, respectively. Reaction times to remote pairs was shorter than reaction times to adjacent pairs for all four Ss. Figure 2 presents the reaction time profile for each of the four Ss.

Insert Figure 2 about here

As can be seen, the hypothesis was supported. For all four Ss, reaction times were shortest to sentences beginning with A. Two Ss (MB and RL) demonstrated uniformly short reaction times to sentences beginning with D. The remaining two Ss did not show this effect.

Experiment 3

Except for test sentences beginning with an end term, the present model contends that reaction time is an inverse function of distance; the more remote the pair, the shorter the reaction time. Though the present data satisfy the ordinal predictions of a distance model quite well, one could question whether the distance assumption was really necessary. Is it possible that the presence or absence of end terms might be enough in and of itself to account for the data? Potts (1972) argued that it was, and described a strategy whereby Ss answered each test question (except B > C? and C > B?) on the basis of the end terms it contained. This model was altered here because of the obvious successes of the distance assumption. With a four-term ordering, however, the effects of distance are confounded with the presence or absence of end terms. Hence, this issue cannot be decided convincingly on the basis of the data presented so far. The resolution of this question has important implications for theories of semantic memory, for if the short reaction time to the remote pairs can be explained merely by arguing that remote pairs are more likely to contain an end term, then any of these models could be altered fairly easily to account for this effect.

Scholz and Potts (1974) examined the profile of accuracy scores for the 15 pairs comprising a six-term ordering. They concluded that both the distance separating the terms of a pair and the presence or absence of end terms were critical factors in determining proportion correct for that pair. Unfortunately, the overall proportion correct in that study was very low, making it impossible to interpret the reaction time data. As explained earlier, however, such reaction time data are critical if one wishes to test the adequacy of a memory model (such as that of Anderson and Bower, 1973) which allows that Ss do store deducible information. Experiment 3 was designed to determine whether reaction time remains an inverse function of distance when the confounding with number of end terms is eliminated.

Method

Subjects were 24 Dartmouth College undergraduates who participated to fulfill a course requirement. Each participated in two 40-min sessions with one day intervening between sessions.

The study materials consisted of a set of 12 paragraphs, each describing a single six-term linear ordering. The terms of the ordering were subject to the same constraints employed previously. The ordering was established by presenting the five adjacent pairs in the chained order: $A > B$, $B > C$, $C > D$, $D > E$, $E > F$. Subjects studied half of the paragraphs during each session. As before, the first paragraph of each session was treated as a warm-up and was not scored. Subjects were given as much time as they desired to study each paragraph and were then tested on the information contained in that paragraph.

The test materials for each paragraph consisted of 30 sentences (15 true and 15 false) describing all possible pair-wise relations between the terms of the ordering. Responses and their reaction times were again entered manually onto the Dartmouth Time-Sharing System, and after each block of 30 sentences Ss were informed of the number of errors they had made. The arrangement of the response buttons was again counterbalanced across Ss, and the arrangement for a particular S was reversed for the second session.

Results and Discussion

Overall proportion correct was .97. Overall reaction times to the adjacent and remote pairs were 2.39 and 1.97 sec, respectively. Averaging over paragraphs, this superiority on the remote pairs was demonstrated by all 24 Ss; averaging over Ss, it was found for all 10 scored paragraphs. To understand the nature of this effect, examine the reaction time profile presented in Figure 3.

Insert Figure 3 about here

The importance of the end terms (A and F) was again apparent. Reaction times were uniform and fastest to the five test sentences beginning with the first term in the ordering (A) and fairly fast to test sentences beginning with the last term in the ordering (F). The familiar interaction between specific pair tested and truth value of the test sentence was also apparent. For the six pairs which contained no end term, reaction time was approximately 240 msec shorter on true sentences than on false sentences. Excluding the two test sentences which contained both end terms (A > F? and F > A?), reaction times to true sentences containing the term A were also shorter than reaction times to false sentences containing the term A, but the difference (660 msec) was much larger than for pairs comprised of inner terms. The effect was reversed in the case of test sentences containing an F. Again excluding the two sentences which contained both end terms, reaction times to true test sentences containing the term F were longer than reaction times to false sentences containing an F.

Though the effects of the end terms were readily apparent, it is equally clear that this was not the only factor operating. If the presence or absence of end terms were the only critical factor, then one would expect to find that reaction times to all pairs containing an end term were shorter than reaction time to any pair not containing an end term. While this was generally the case, there was a glaring exception in that reaction time to sentences testing the remote inner pair B > E (B > E? and E > B?) were noticeably shorter than reaction times to several pairs containing an end term. Also, when all pairs containing an end term were eliminated from the analysis, average reaction times to the remaining remote and adjacent pairs were 2.38 and 2.67 sec, respectively. This superiority of the remote pairs was demonstrated by 23 of the 24 <u>S</u>s.

A simple distance hypothesis makes a total of 55 ordinal predictions for a six-term ordering.[3] Among the true sentences, all but two of these predictions were satisfied. The only violations were that reaction time to the sentence A > D? was shorter than reaction time to the sentence A > E?, and that reaction time to the sentence E > F? was shorter than reaction time to the sentence D > F?. Similarly, among false sentences all but one of the 55 predictions was satisfied. The only violation was that reaction time to the sentence B > A? was shorter than reaction time to the sentence C > A?. Among the pairs consisting of inner terms, no ordinal predictions were violated for either true or false sentences.

General Discussion

The model proposed to account for the present data is basically a distance model which argues that the more remote a pair, the shorter the reaction time to that pair. This assumption accounts for a large portion of the present data. The observed interaction between specific pair tested and truth value of the test sentence is problematical to such a model, however. The data seem to indicate that this interaction is due to the fact that reaction times to test sentences beginning with an end term are unusually short. Hence, reaction times to true sentences which begin with the first term in the ordering are shorter than reaction times to false sentences which end with the first term in the ordering. Similarly, reaction times to false sentences which begin with the last term in the ordering are shorter than reaction times to true sentences which end with the last term in the ordering.

As stated earlier, the basic finding that reaction time is shorter to remote pairs than to adjacent pairs is in direct contradiction to several current models of how meaningful information is stored. Certainly any model, such as that of Quillian (1969), which argues that Ss do not store deducible information is totally incapable of accounting for this result. However, not even Anderson and Bower's model of human associative memory, which does have a mechanism whereby Ss can store deducible information, can account for this result. Its weakness lies in its reliance on simple associative links between items to describe the nature of stored information. For all their complexity, most current models of semantic memory share the same weakness (e.g., Rumelhart, Lindsay, & Norman, 1972).

If the model originally proposed by Potts (1972) had been correct in arguing that reaction time to the remote pairs reflected only Ss' use of the end terms as a strategy for responding, then any of these models could have been altered fairly easily to account for this effect. However, the present results indicate that reaction time to remote pairs is shorter than reaction time to adjacent pairs even when all test sentences containing an end term are eliminated from the analysis. This poses more of a difficulty for these models. How much of a difficulty depends on the nature of the comparison process which leads to the obtained inverse function between distance and reaction time.

Moyer (1973) has shown that reaction time for determining which of two animals is larger is a monotonic decreasing function of the difference in size between the animals; the larger the size difference, the shorter the reaction time. In an attempt to explain this finding, Moyer hypothesized the existence of an "internal psychophysics". He argued that Ss stored in memory actual perceptual representations of the sizes of various animals and responded to the questions by performing actual perceptual comparisons. The more jnd's of size separating the two animals being compared, the faster the response. If Moyer's hypothesis is correct and if a similar mechanism underlies the distance effect in the present experiments, then the currently popular associative models of memory could not account for this effect without introducing an entirely new set of principles.

There is an alternative explanation for the distance effect which would be considerably easier to incorporate into current models, however, In attempting to learn the six-term orderings of Experiment 3, Ss frequently reported learning the ordering in two distinct parts. The reported that exactly where the ordering was broken varied with different paragraphs but that they could respond considerably faster to a test sentence when the two terms of that sentence belonged to different halves of the ordering. If these intuitions are correct, then the distance effect could be explained by noting that the more terms intervening between two terms in a particular test sentence, the more likely it will be that the two terms will belong to different halves of the ordering. If the place at which an ordering is broken is indeed variable, this would explain the obtained inverse relationship between reaction time and distance.

Such a model could be formalized in terms similar to Clark's (1969) notion of the primacy of functional relations. For items in the first half of the ordering, along with information as to the exact magnitude or position of each item, Ss might also store the information that the item was good (tall, fast, etc.). For items in the second half of the ordering, Ss might store the information that the item was bad (short, slow, etc.). If the two items in a test sentence were from different halves of the ordering, Ss would not need to compare actual magnitudes or positions; they could respond by merely noting that one was good and one was bad. Consequently, reaction times in these cases would be shorter than when the two terms belonged to the same half of the ordering.

The present experiments do not enable us to decide between these two alternative explanations, so final resolution of the issue must await further empirical data.

References

Anderson, J. R., & Bower, G. H. Human associative memory. New York: Wiley, 1973.

Barclay, J. R. The role of comprehension in remembering sentences. Cognitive Psychology, 1973, 4, 229-254.

Bransford, J. D., Barclay, J. R., & Franks, J. J. Sentence memory: A constructive versus interpretive approach. Cognitive Psychology, 1972, 3, 193-209.

Bransford, J. D., & Franks, J. J. The abstraction of linguistic ideas. Cognitive Psychology, 1971, 2, 331-350.

Clark, H. H. Linguistic processes in deductive reasoning. Psychological Review, 1969, 76, 387-404.

Moyer, R. S. Comparing objects in memory: Evidence suggesting an internal psychophysics. Perception and Psychophysics, 1973, 13, 180-184.

Potts, G. R. Information processing strategies used in the encoding of linear orderings. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 727-740.

Potts, G. R. Memory for redundant information. Memory and Cognition, 1973, 1, 467-470.

Quillian, M. R. The teachable language comprehender. Communications of the ACM, 1969, 12, 459-476.

Rumelhart, D. E., Lindsay, P. H., & Norman, D. A. A process model for long-term memory. In E. Tulving & W. Donaldson (eds.), Organization of Memory. New York: Academic Press, 1972.

Scholz, K. W., & Potts, G. R. Cognitive processing of linear orderings. In press, Journal of Experimental Psychology.

Young, R. K. Serial learning. In Dixon, T. R., & Horton, D. L., Verbal Behavior and General Behavior Theory. New Jersey: Prentice-Hall, 1968.

Footnotes

1. Portions of this paper were presented at the 1973 meetings of the Psychonomic Society, St. Louis, Missouri.

2. It should be noted that the designation of one end term of the ordering as A and one as D is not arbitrary. When taking notes, subjects are consistent in arranging the terms of the ordering in such a way that the best, tallest, largest, etc., is on the top or left. This term is designated as A. The worst, shortest, smallest, etc., term is consistently placed on the bottom or right. This term is designated as D.

3. The ordinal predictions of a distance model can be formalized as follows. Let the first (A) through kth terms in the ordering be represented by the numbers one through k, respectively; let $D(ij)$ represent the spatial distance between the items i and j on the scale; and let $RT(ij)$ represent the reaction time to a pair consisting of the items i and j. The basic prediction of a distance model is that the $RT(ij)$ are a monotonic decreasing function of the $D(ij)$. In other words, for any i, j, m, and n, $RT(ij) = RT(mn)$ if and only if $D(ij) = D(mn)$, and $RT(ij) < RT(mn)$ if and only if $D(ij) > D(mn)$. If one examines the nature of a linear scale, it becomes apparent that $D(ij) > D(mn)$ whenever $i \leq m$ and $j \geq n$. (The only exception is the trivial case where both $i = m$ and $j = n$, and this case can be ignored in the present analysis.) Thus, a distance model would predict that $RT(ij) < RT(mn)$ whenever $i \leq m$ and $j \geq n$.

Table 1

Sample Paragraph Used in Experiments 1, 2, and 3

In art class, Sally showed her nature painting to the teacher. Her teacher felt that certain parts of the picture were drawn better than others. The teacher said her tree was better than her grass, her sky was better than her bird, and her bird was better than her tree. Upon hearing this, Sally decided to drop art and major in psychology.

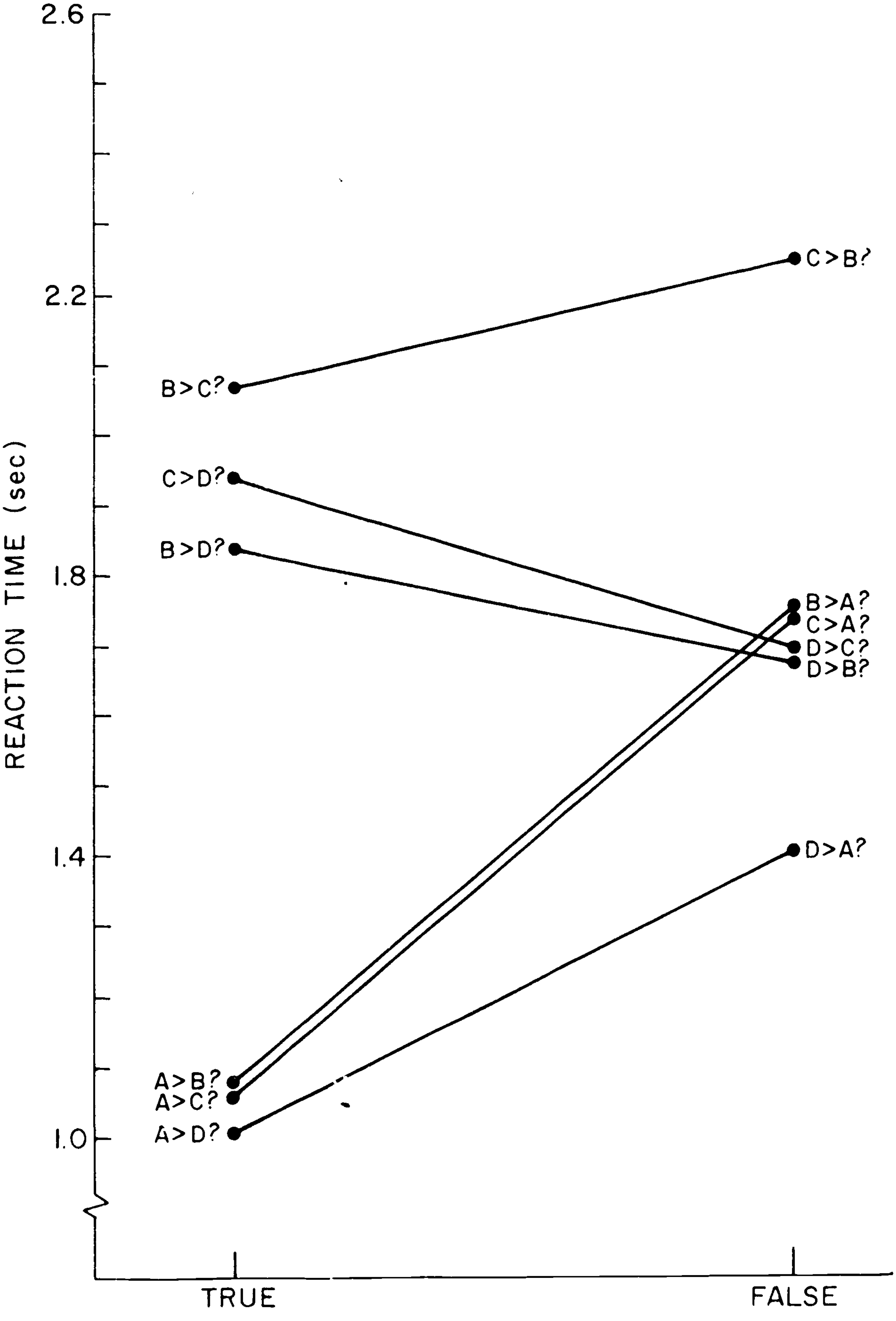

Figure 1. Reaction time profile of the 12 test sentences used in Experiment 1.

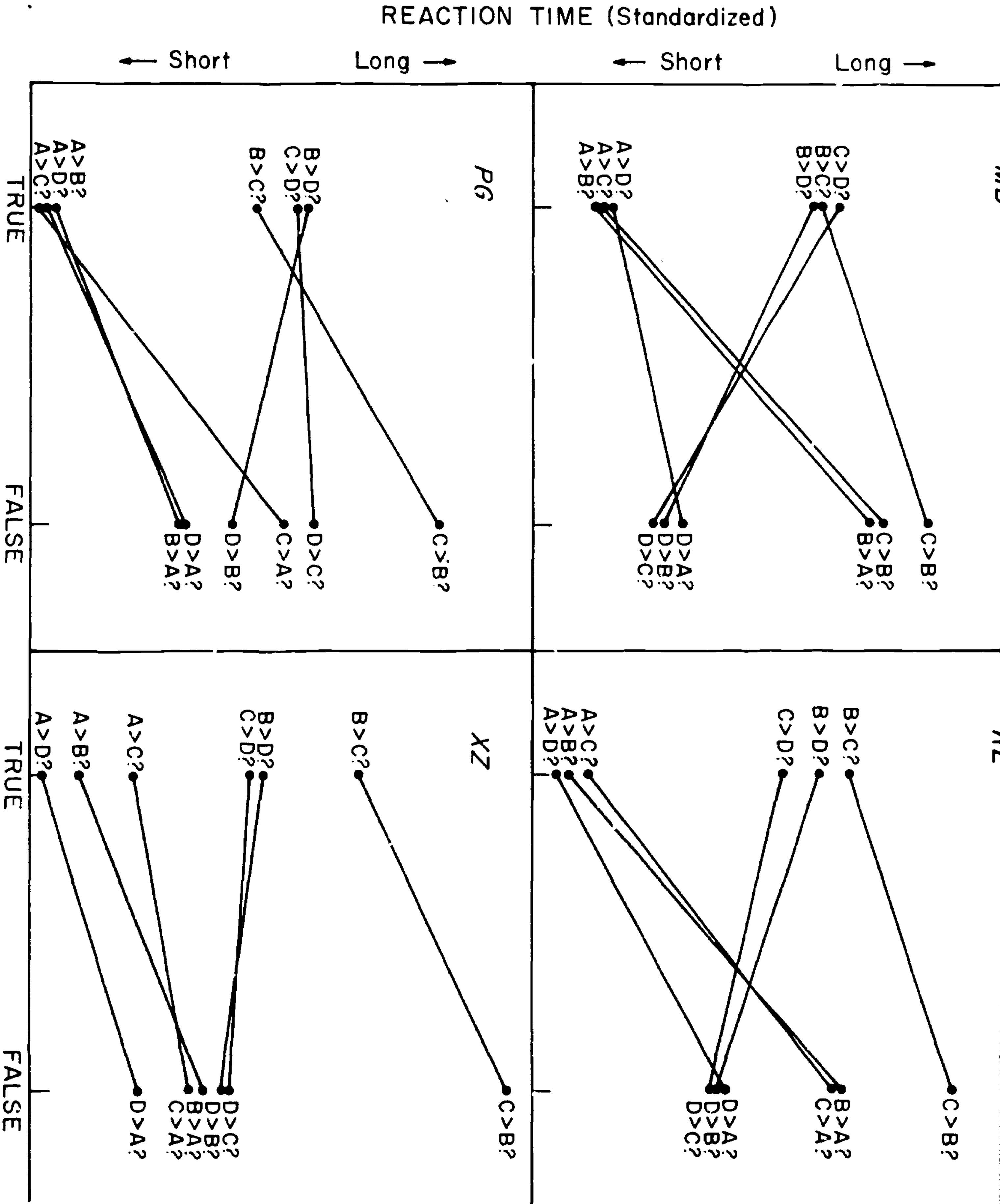

Figure 2. Reaction time profiles for the four subjects in Experiment 2.

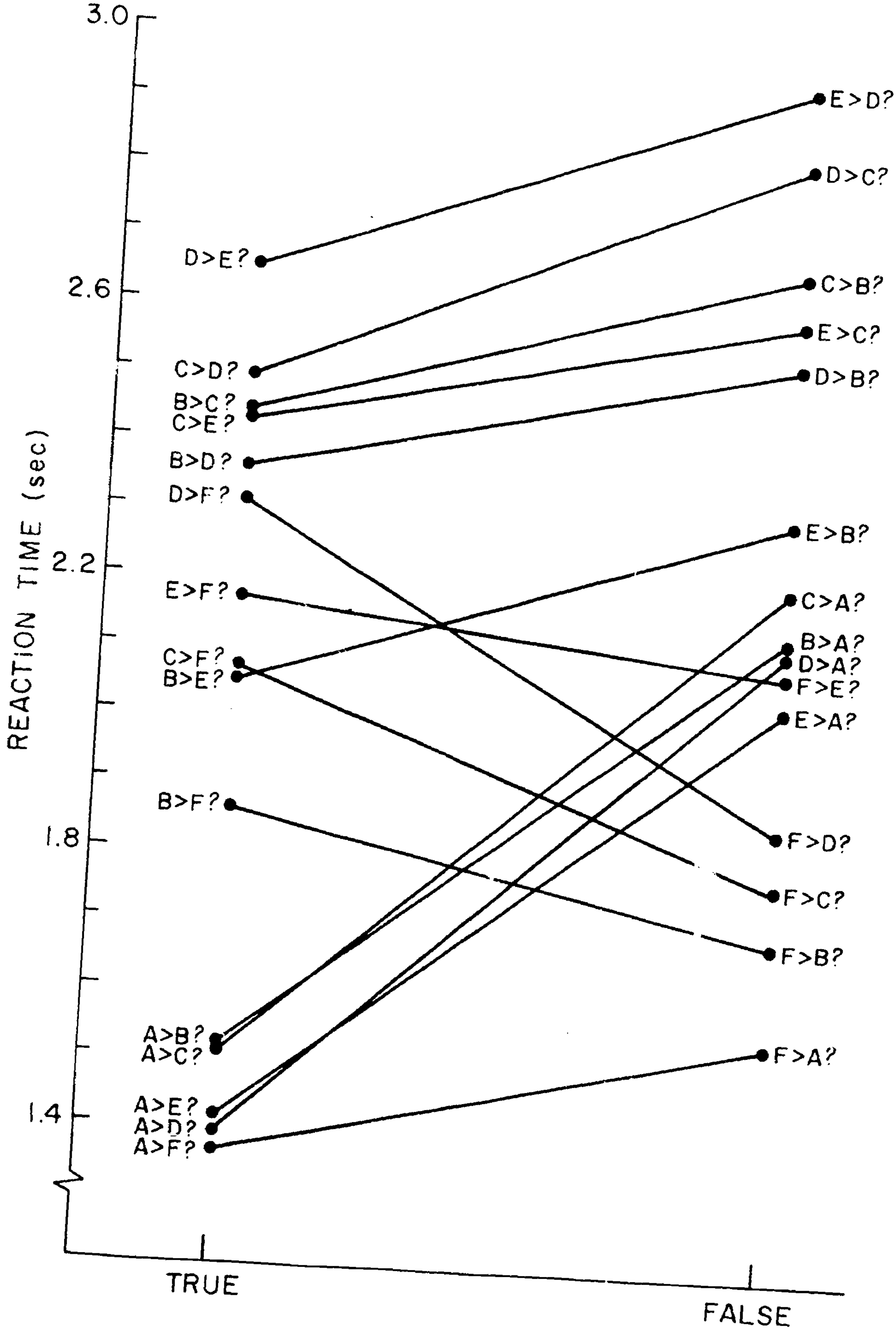

Figure 3. Reaction time profile of the 30 test sentences used in Experiment 3.